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TITLE: **VEHICULAR OCCUPANT RESTRAINT**

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VEHICULAR OCCUPANT RESTRAINT

BACKGROUND OF THE INVENTION

This invention relates generally to vehicular occupant restraint and, more particularly, to pressure activated restraint system devices as well as related or associated methods of gas generation and compositions used in such gas generation.

Vehicular occupant restraint systems that include or incorporate actuatable restraint devices are known in the art. In such systems, the restraint device is typically actuated upon the occurrence of a condition during which a vehicle occupant is to be restrained. An example of a condition for which a vehicle occupant is customarily desired to be restrained is a vehicle collision.

One well-known type of actuatable restraint system seeks to protect a vehicle occupant using a cushion or bag, e.g., an "airbag cushion," that is inflated or expanded with gas when the vehicle encounters sudden deceleration, such as in the event of a collision. In such inflatable restraint systems, the airbag cushion is normally housed in an uninflated and folded condition to minimize space requirements. Such systems typically also include one or more crash sensors mounted on or to the frame or body of the vehicle to detect sudden decelerations of the vehicle and to electronically trigger activation of the system. Upon actuation of the system, the cushion begins to be inflated in a matter of no more than a few milliseconds with gas produced or supplied by a device commonly referred to as an "inflator."

Many types of inflator devices have been disclosed in the art for the inflating of one or more inflatable restraint system airbag cushions. Inflator devices which form or produce inflation gas via the combustion of a gas generating material, i.e., a "gas generant," are well known. It is also known that certain of such inflator devices may use such generated gas to supplement stored and pressurized gas by the addition of high temperature combustion products, including additional gas products, produced by the burning of the gas generating material to a supply of the stored, pressurized gas. In some cases, the combustion products produced by the burning of a gas generating material may be the sole or substantially the sole source for the inflation gas issuing forth from a particular inflator device.

It is common that inflator devices include an initiator, such as a squib, and an igniter. For example, common initiator devices used in such applications include: bridgewire, spark-discharge, heated or exploding wire or foil, through bulkhead (e.g., an initiator which discharges through a bulkhead such as in the form of a metal hermetic seal), and may, if desired, optionally contain a desired load of a suitable pyrotechnic charge. In practice, upon receipt of an appropriate triggering signal from a crash or other selected deceleration sensor, the initiator activates causing the rapid combustion of the igniter material, which, in turn, ignites the gas generant, such as in the form of tablets or wafers. In typical such inflator devices, it is common that a squib is used to ignite an igniter composition which is usually present in a separate compartment or canister. In this manner, the igniter material is generally

physically separated from both the squib and the gas generant. In some cases, however, the igniter material may be present as a coating such as applied directly onto the gas generant tablets or wafers with an electrically actuated squib still being used to ignite the igniter material. In such case, though the igniter material is physically joined or in contact with the gas generant, both the igniter material and the gas generant are physically separated from the squib components. Very seldom, if ever, is a granular igniter composition physically mixed with gas generant tablets or wafers to effect ignition thereof.

Commonly desired features or performance criteria for inflatable restraint system igniter compositions include:

1. ignitability via typical squib charges such as by means of primary explosives such as zirconium/potassium perchlorate or lead trinitroresorcinate, for example;

2. upon combustion, having a high heat of explosion;

3. ease and safety of manufacture and production;

4. exhibit minimal or reduced ignition delays, e.g., ignite a gas generant composition within an inflator device within about 10 milliseconds, preferably within about 8 milliseconds or less and, even more preferably, at least in certain applications, within about 5 milliseconds or less; and

5. produce or result in relatively low levels of various undesirable effluent gases such as nitric oxide (NO), ammonia (NH_3) and carbon monoxide (CO), for example.

Typical igniter compositions used in such applications are composed of a metallic fuel and selected oxidizer. Common useful metallic fuels for such compositions include boron, zirconium, titanium and silicon, for example. Typical or common oxidizers used in such compositions include alkali metal perchlorates, chlorates and nitrates. One such igniter formulation common or standard for use in airbag inflators is composed of about 15 to about 30 weight percent (typically about 25 weight percent) boron and about 70 to about 85 weight percent (typically about 75 weight percent) potassium nitrate. In the art, this standard igniter formulation is commonly referred to as "$BKNO_3$."

Unfortunately, typical igniter compositions, such as $BKNO_3$, are generally deficient in one or more of the above-identified criteria. Further, such typical igniter compositions may commonly burn at very high combustion temperatures, such as temperatures of up to about 3000 K. Also, the gas fraction produced by reaction of such igniter compositions is generally relatively low.

Another type of vehicular actuatable occupant restraint system has or includes a seat belt which is extendable across a vehicle occupant and includes an actuatable device, such as a pretensioner, provided to move at least a portion of the seat belt relative to the occupant. For example, one modern seat belt is known as a

3-point restraint because it is secured to the vehicle at three points arranged about the vehicle occupant to provide a diagonal torso section and a horizontal lap portion to hold the vehicle occupant in the seat. The belt is customarily attached to the vehicle by a spring-loaded retractor tending to tighten in the belt, and by a buckle for quick release of the belt. Seat belt pretensioners are typically sited at the retractor or at the buckle end of the restraining seat belt. Seat belt pretensioners are commonly designed to store energy which, when released, effects the pretensioning operation. This energy may be mechanical energy in the form of a stressed spring, but more modern pretensioners are commonly pyrotechnically operated. Pyrotechnically operated pretensioners comprise a sealed tube containing a gas generant composition which reacts rapidly to generate gas which expands rapidly to provide the energy to effect the pretensioning operation. For example, such generated gas may be used to drive a piston or the like, such as included or used in a pretensioner, in association with a seat belt or other restraint device. In view of the relatively small amount of gas generated or produced from or in such devices, as compared to gas generating inflators typically used in the inflation of inflatable restraint system airbag cushions, such devices are commonly referred to as "micro-gas generators."

Micro-gas generators are generally composed of a single housing which contains an initiation element such as in the form of squib, an intermediate igniter composition and a high output, gas generating material. Squibs used in such devices typically include a heated bridgewire to which has been applied a thermally sensitive

very hot burning initiator composition however, other known initiation elements can, if desired be used. Thus, micro-gas generators are typically very small devices which generally contain the components of an airbag inflator, including an initiation element, igniter composition and a high output, gas generating material without the degree of physical separation typically present in airbag inflators. Further, due to the very small operating time requirements associated with micro-gas generator applications (such as operating times of about 6 milliseconds or less), such devices generally contain a much larger ratio of igniter material to gas generating material, as compared to typical airbag inflator devices. For example, inflators used in association for inflation of frontal impact airbag cushions employed for driver protection typically contain or include igniter material in a range of about 3-10% by weight of the total gas producing material (e.g., igniter material and gas generating output charge) present in the inflator device. In contrast, in micro-gas generators, the igniter material may generally be present within the device in a relative amount of at least about 20% by weight of the total gas producing material present therewithin and typically in a range of about 20-50% by weight of the total gas producing material present in the device.

Commonly assigned, Barnes et al., U.S. Patent 6,132,480, issued 17 October 2000, whose disclosure is hereby incorporated by reference, discloses an igniter composition for a gas generant in airbag inflation applications and related methods of gas generation. The igniter compositions and methods of gas generation of this patent include a boron fuel component (e.g., about 10 to about 25, preferably

about 15 to about 20 composition weight percent), an oxidizer component (e.g., about 55 to about 80 composition weight percent) and a gas-producing fuel component, such as guanidine nitrate, (e.g., at least about 10 to about 25, preferably about 15 to about 25 composition weight percent).

While such igniter compositions and related methods of gas generation are generally effective in alleviating at least some of the concerns or overcoming at least some of the problems of inflatable restraint system igniter compositions, further improvements are desired or required for at least certain particular applications. For example, a desirable feature of micro-gas generator devices used in or in connection with seat belt pretensioners is the production of a relatively large quantity of gas from a relatively small volume. In addition, it is desirable that such gas generator devices minimize or avoid the production of substantial amounts of possibly undesirable effluent gases such as carbon monoxide and nitric oxide, for example, and which undesirable effluent gases might somehow escape into the vehicle interior and thus come into contact with the occupant(s).

Thus, there is a need and a demand for improvements in igniter compositions and related methods of gas generation such as desired or suitable for use in occupant restraint system devices such as micro-gas generators such as in the form of a seat belt pretensioner. In this regard, there is a particular need and demand for such igniter compositions, related methods of gas generation and corresponding occupant restraint system devices which are preferably effective in minimizing or

reducing ignition delays, e.g., ignite a gas generant composition within an occupant restraint system device within about 1 millisecond, preferably within about 0.25 milliseconds or less and, even more preferably, at least in certain applications, within a delay time on the order of about 0.1 milliseconds, while also minimizing or avoiding the production of various undesirable effluent gases such as nitrous oxide (N_2O), nitric oxide (NO), ammonia (NH_3) and carbon monoxide (CO), for example.

SUMMARY OF THE INVENTION

A general object of the invention is to provide an improved igniter composition and method of generating gas suitable for use in gas generation in connection with a motor vehicle occupant restraint system such as a micro-gas generator such as a seat belt pretensioner or the like.

A more specific objective of the invention is to overcome one or more of the problems described above.

The general object of the invention can be attained, at least in part, through an igniter composition which includes a fuel component containing at least about 3 composition weight percent and less than 15 composition weight percent of boron and an oxidizer component containing at least one oxidizer material selected from the group consisting of alkali metal nitrates, alkaline earth metal nitrates and mixtures thereof. In accordance with a preferred embodiment of the invention, the fuel component and the oxidizer component are present in stoichiometrically balanced amounts.

The prior art generally fails to provide igniter compositions and methods of generating gas suitable for use in gas generation in connection with a motor vehicle occupant restraint system such as a micro-gas generator such as a seat belt pretensioner or the like, which igniter compositions and gas generation methods minimize, avoid or otherwise desirably prevent formation or generation of significant amounts of incomplete products of combustion, such as carbon monoxide.

The invention further comprehends an occupant restraint system device which includes a housing containing a supply of reactant material. In accordance with a preferred embodiment of the invention of such aspect of the invention, such a reactant material includes a fuel component containing at least about 3 composition weight percent and less than 15 composition weight percent of boron and an oxidizer component containing at least one oxidizer material selected from the group consisting of alkali metal nitrates, alkaline earth metal nitrates and mixtures thereof, wherein the fuel component and the oxidizer component are present in stoichiometrically balanced amounts. Particular embodiments relating to this aspect of the invention include a seat belt pretensioner and a micro-gas generator, for example.

The invention still further comprehends a method of generating gas suitable for use in an occupant restraint system of a motor vehicle. Such a method involves igniting a supply of a specified igniter composition to form igniter composition reaction products and contacting a supply of a gas generant composition with the igniter composition reaction products to form product gas. In accordance

with one preferred embodiment of the invention, the igniter composition contains a fuel component containing at least about 3 composition weight percent and less than 15 composition weight percent of boron, and an oxidizer component containing at least one oxidizer material selected from the group consisting of alkali metal nitrates, alkaline earth metal nitrates and mixtures thereof. Further, the fuel component and the oxidizer component are desirably present in such a composition in stoichiometrically balanced amounts.

As used herein, references to a specific composition, component or material as a "fuel" are to be understood to refer to a chemical which generally lacks sufficient oxygen to burn completely to CO_2, H_2O and N_2.

Correspondingly, references herein to a specific composition, component or material as an "oxidizer" are to be understood to refer to a chemical generally having more than sufficient oxygen to burn completely to CO_2, H_2O and N_2.

References to "stoichiometrically balanced amounts" of fuel and oxidizer components in a composition are to be generally understood to refer to those compositions which include or contain components in sufficient relative amounts such as to minimize or avoid the production of significant amounts of incomplete products of combustion such as CO and NO, for example. More particularly, as used herein, a fuel component and the oxidizer component are considered present in stoichiometrically balanced amounts if the composition contains no more than about

± 4 weight percent of the amount of fuel (other than boron) and oxidizer required for complete burning to CO_2, H_2O and N_2.

Other objects and advantages will be apparent to those skilled in the art from the following detailed description taken in conjunction with the appended claims and drawing.

BRIEF DESCRIPTION OF THE DRAWING

The Figure is a simplified schematic, in a partially broken away view, of a micro-gas generator device in accordance with one embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention provides an igniter composition such as for a gas generant material used in pressure activated restraint system devices such as micro-gas generator applications such as seat belt pretensioners. Such combustible igniter compositions typically include a fuel component containing at least about 3 composition weight percent and less than 15 composition weight percent of boron and an oxidizer component, wherein the fuel component and the oxidizer component are present in stoichiometrically balanced amounts.

Turning to the Figure, there is illustrated a micro-gas generator device generally designated by the reference numeral 10, in accordance with one preferred embodiment of the invention. In particular, the micro-gas generator 10 is shown as having the general form of a device such as may find desirable application in the

driving of a piston or the like such as may be desired in a seat belt pretensioner or like apparatus.

The micro-gas generator 10 includes a housing 12 forming a chamber 14. The housing 12 is at least in part defined by an elongated generally cylindrical sleeve 16, having an open first end 20 and a closed second end 22 and may desirably be formed in a one piece construction. As will be appreciated, such a construction desirably may serve to reduce or eliminate the number of welds needed or used in the construction such as by eliminating the need for the welding of an end closure such to close one or more ends of the housing 12.

An initiator, such as in the form of a heated bridgewire squib and containing a desired load of a suitable pyrotechnic charge and such as known in the art, here generally designated by the reference numeral 24, is suitably joined or otherwise connected to the sleeve first end 20 and such as to close such first end. The initiator 24 includes or has two electrode pins 26 and 28. The electrode pins 26 and 28 are in signal receiving communication with one or more sensors (not shown) such as known in the art and such as effective to send a signal to the initiator 24 to effect the desired actuation thereof.

As will be appreciated by those skilled in the art and guided by the teachings herein provided, other suitable forms of initiator devices, such as known in the art, can if desired be used in the practice of the invention. For example, such other suitable forms of initiator devices can include spark-discharge, heated or exploding

wire or foil and through bulkhead initiators, and may, if desired, optionally contain a desired load of a suitable pyrotechnic charge. Thus, it is to be understood that the broader practice of the invention is not necessarily limited to the incorporation and/or use of a heated bridgewire squib.

The housing 12 contains or otherwise includes a supply of igniter composition, generally designated by the reference numeral 30. As described in greater detail below and in accordance with a preferred embodiment, the invention desirably employs an igniter composition which avoids or otherwise prevents formation or generation of significant amounts of incomplete products of combustion, such as carbon monoxide, while satisfying the stringent demands relating to igniter materials employed in micro-gas generators such as in the form of seat belt pretensioners.

The initiator 24 and the supply of igniter composition 30 are situated such that upon actuation, the initiator 24 and the supply of igniter composition 30 are in reaction-initiating communication such that actuation of the initiator 24 results or otherwise produces reaction of at least a portion of the supply of igniter composition 30. In the particular illustrated embodiment, the initiator 24 and the supply of igniter composition 30 are in direct contact.

The housing 12 also contains or otherwise includes a supply of gas generant material, such as is known in the art and generally designated by the reference numeral 34. Various gas generant materials such as known in the art can be

used in the practice of the invention. For example, suitable gas generant materials for use in the practice of the invention may constitute a mixture of guanidine nitrate and basic copper nitrate. Another suitable gas generant material for use in the practice of the invention may constitute a mixture of guanidine nitrate, copper diammine dinitrate and ammonium nitrate, for example.

While the supply of gas generant material 34 is shown as being in the form of wafers, it is to be understood that the broader practice of the invention is not necessarily limited to the incorporation and use of particular or specific forms of gas generant materials. Thus, other suitable forms of gas generant materials, including for example, tablets, may be used if desired.

Operation

Typical operation of the micro-gas generator 10, shown in the Figure, is as follows:

Upon the sensing of an occurrence for which actuation of the micro-gas generator 10 is desired, an electrical signal is sent to the initiator 24. The initiator 24 functions to ignite the supply of igniter composition 30 such as to form igniter composition reaction products. The igniter composition reaction products contact the supply of gas generant material 34, resulting in the ignition thereof and the formation of a product gas. In those applications where, for example, the micro-gas generator 10 is a seat belt pretensioner, such product gas can be employed to drive a piston to

appropriately tighten the seat belt. The product gas may then be appropriately vented from such piston assembly, such as into the passenger compartment of the vehicle and such as known in the art.

As identified above, the invention desirably employs an igniter composition which avoids or otherwise prevents formation or generation of significant amounts of incomplete products of combustion, such as carbon monoxide, while satisfying the stringent demands relating to igniter materials employed in micro-gas generators such as in the form of seat belt pretensioners.

Igniter compositions in general accord with the invention desirably include a fuel component generally containing at least about 3 composition weight percent and less than 15 composition weight percent of boron and an oxidizer component, with the fuel component and the oxidizer component present in stoichiometrically balanced amounts. Further, while igniter compositions of the invention may advantageously contain such boron fuel component in a relative amount in the range of at least about 3 composition weight percent and less than 15 composition weight percent, certain preferred embodiments of the invention may include or contain such boron fuel component in a relative amount of less than 10 composition weight percent, with those igniter compositions which include or contain such boron fuel component in a relative amount in the range of at least about 7 composition weight percent and less than about 10 composition being particularly preferred as such compositions generally provide a suitable and desired ease of

ignitabilty while simultaneously providing a sufficiently high gas output to permit the incorporation and use of micro-gas generators designed to have a desirably small volume.

In accordance with certain preferred embodiments of the invention, the igniter compositions used in the practice of the invention may also include or contain at least one fuel material that produces gas on reaction with the at least one oxidizer material. Gas-producing fuel component materials which are organic in nature are particularly preferred. In particular, organic gas-producing fuel component materials useful in the practice of the invention can advantageously take the form of a nitrate of at least one amine or urea derivative. Examples of such materials include, but are not limited to, guanidine nitrate, ethylenediamine dinitrate, urea nitrate and semicarbazide nitrate.

In general, guanidine nitrate has been found to be a particularly desirable gas-producing fuel component for use in the practice of the invention. The desirability of the use of guanidine nitrate in the igniter compositions of the invention is generally based on a combination of factors such as relating to cost, stability (e.g., thermal stability), availability and compatibility (e.g., compatibility with other standard or useful igniter composition ingredients, for example).

Igniter compositions in accord with the invention generally include such gas-producing fuel component in a relative amount of generally less than about 60 composition weight percent and preferably less than about 50 composition weight

percent, with those compositions wherein such gas-producing fuel component is present in a relative amount in the range of about 0 to about 48 composition weight percent being generally particularly preferred. Certain preferred embodiments of the invention, particularly those wherein the gas-producing fuel component comprises guanidine nitrate, may include or contain such gas-producing fuel component in a relative amount of at least about 8 composition weight percent and, preferably, in the range of at least about 20 to no more than about 40 composition weight percent or preferably, as may be desired in certain particular embodiments, in the range of about 20 to about 30 composition weight percent.

Useful igniter composition oxidizers include alkali or alkaline earth metal nitrates, particularly preferred are the nitrates of sodium, potassium, and strontium with potassium nitrate being a particularly preferred oxidizer component for use in the practice of the invention. While the chlorates and perchlorates of alkali and alkaline earth metals, if desired, could be used, such chlorates and perchlorates generally exhibit too great a sensitivity to satisfy most practical inflatable restraint applications.

In practice, preferred igniter compositions for use in the practice of the invention contain such an oxidizer component in a relative amount of between about 40 to about 85 composition weight percent. One particularly preferred igniter composition contains about 55 to about 75 composition weight percent of potassium nitrate oxidizer component.

As identified above, the igniter fuel component and the igniter oxidizer component are desirably present in stoichiometrically balanced amounts. Thus, the igniter compositions of the invention desirably contain sufficient oxidizer to oxidize all of the boron present in the composition to boron oxide and all of the carbon and hydrogen present in the composition (such as through the gas-producing fuel material such as guanidine nitrate) to carbon dioxide and water, respectively.

As will be appreciated by those skilled in the art and guided by the teachings herein provided, igniter compositions in accordance with the invention can be processed or otherwise produced by various methods. One useful processing technique for igniter compositions in accordance with the invention to form granular materials is accomplished by first slurry mixing the various ingredients together in a 50/50 mixture of water and ethanol (25% by weight) to dissolve some of the guanidine nitrate. The slurry mixture is then dried in an oven to form a product cake. This product cake can then be ground, with the ground product classified to the specified size (e.g., on the order of about 14 to about 30 mesh). Alternatively, the slurry may be granulated, dried and then classified. Another processing or production method that may be employed is to form a slurry at a relatively low solvent level and then sphereonize the material, followed by drying the material such as in an oven or fluid bed drier and classification.

The present invention is described in further detail in connection with the following example which illustrates or simulates various aspects involved in the

practice of the invention. It is to be understood that all changes that come within the spirit of the invention are desired to be protected and thus the invention is not to be construed as limited by this example.

EXAMPLE

A preferred igniter composition in accordance with the invention was prepared containing 9 weight percent boron, 24.37 weight percent guanidine nitrate and 66.63 weight percent potassium nitrate, where such percentages are in terms of the overall composition.

This preferred igniter composition was found to have a linear burn rate of 0.98 inches per second, a flame temperature of 2919 kelvin, a pressure times volume product (PV) of 550 liter atmospheres per 100 grams of composition, and a gas output of 2.30 moles per 100 grams of composition.

These results indicate that only a small quantity of the subject igniter material composition is required in a seat belt pretensioner device to effectively make the device functional. The PV ratio value of 550 liter atmospheres per 100 grams of composition provides a measure of the ability of the composition to drive a piston to effect desired seat belt tightening. The composition exhibits a burn rate which is sufficiently high to ensure that such tightening is accomplished within the generally desired or allowed time period of about 6 milliseconds. Further, as the material is granular in form and about 10 to 300 mesh, the material has a desirably high surface

area. The high burn rate combined with the high surface area exhibited by the subject material indicates that the material can easily be burned and produce gas within such allowed 6 millisecond limit.

Thus, the invention provides igniter compositions and methods of generating gas suitable for use in gas generation in connection with a motor vehicle occupant restraint system such as a micro-gas generator such as a seat belt pretensioner or the like, which igniter compositions and gas generation methods minimize, avoid or otherwise desirably prevent formation or generation of significant amounts of incomplete products of combustion, such as carbon monoxide, while simultaneously satisfying the stringent demands relating to igniter materials employed in such micro-gas generators.

The invention has been described above with reference to particular embodiments wherein the igniter composition of the invention is employed to ignite a gas generant material within a micro-gas generator device. Those skilled in the art and guided by the teachings herein provided will appreciate that, if desired and in accordance with certain embodiments of the invention, the invention can be practiced employing a gas generant material which is similar or the same in composition as the igniter composition of the invention. It is to be understood, however, that the broader practice of the invention is not necessarily so limited. For example, as identified above, other suitable gas generant materials such as known in the art and as may be

selected by one skilled in the art and guided by the teachings herein provided can be used, if desired.

The invention illustratively disclosed herein suitably may be practiced in the absence of any element, part, step, component, or ingredient which is not specifically disclosed herein.

While in the foregoing detailed description this invention has been described in relation to certain preferred embodiments thereof, and many details have been set forth for purposes of illustration, it will be apparent to those skilled in the art that the invention is susceptible to additional embodiments and that certain of the details described herein can be varied considerably without departing from the basic principles of the invention.